Alteration and Oxidiation of an Olivine Lamprophyre Dike from Southern Utah, USA: An Analog for Mars

Conference or Workshop Item

ALTERATION AND OXIDIATION OF AN OLIVINE LAMPROPHYRE DIKE FROM SOUTHERN UTAH, USA: AN ANALOG FOR MARS. L.J. Costello[1], J. Filiberto[1,2], S.L. Potter-McIntyre[1] J.R. Crandall[1], S.P. Schwenzer[1,2], and D.R. Hummer[1], [1]Southern Illinois University Carbondale, 1259 Lincoln Road, Mailcode 4324, Carbondale, Illinois, 62901, USA (Lacey.costello@siu.edu). [2]School of Environment, Earth, and Ecosystems Sciences, The Open University, Walton Hall, Milton Keynes MK7 6AA, UK.

Introduction: The physical and chemical weathering of iron and magnesium silicates can provide important insights into the overall alteration and oxidation of the host rock, and can be indicative of the environment to which the rock was exposed [1,2]. Olivine is a common mineral present in Martian and terrestrial basalts and weathers readily at Earth surface conditions [2-5]. The process of iron alteration and oxidation may be more prevalent on Mars because Martian basalts usually contain more iron than terrestrial basalts [3,4]. These processes may be more prominet during the Noachian, when the atmosphere was likely warmer and wetter [6]. A thicker atmosphere during the Noachian allows for temperatures to be high enough for liquid water to exist, which could drive alteration and redox reactions [6,7]. However, a detailed study of the process of oxidizing a mafic igneous intrusion and forming altered and oxidized phases with respect to Mars is lacking. Therefore, we investigate the change from a relatively fresh to an altered mafic intrusion in an Earth analog on the Colorado Plateau. The alteration and oxidiation presumably occurred after emplacement and during cooling. This work will constrain the mineralogical changes associated with oxidation as applicable to the alteration of the Martian crust [8].

Geologic setting: Approximately 3.7–4.1 Ma, mafic dikes and sills intruded into the Jurassic sedimentary rocks of the San Rafael Group on the Colorado Plateau [9]. This study focuses on an olivine lamprophyre dike located east of the San Rafael Swell near the Big Flat Tops. The "Flat Top Dike" is located several km east of the main cluster of dikes within the San Rafael Swell. During emplacement, the dike followed a pre-existing, northwest trending system of fractures [9]. The Flat Top Dike is olivine-rich, silica-poor, LREE-enriched, with approximately 20–25 % phlogopite and 15 % calcite [10]. The composition of the dike prior to alteration is indicative of an olivine lamprophyre making it the first documented lamprophyre on the Colorado Plateau [10]. The total length of the exposed dike is approximately 2.6 km [10].

Methods: Samples of the dike were collected during the summer of 2016 and 2017 field seasons. The dike was sampled from each of the four visually distinct sections (Figure 1).

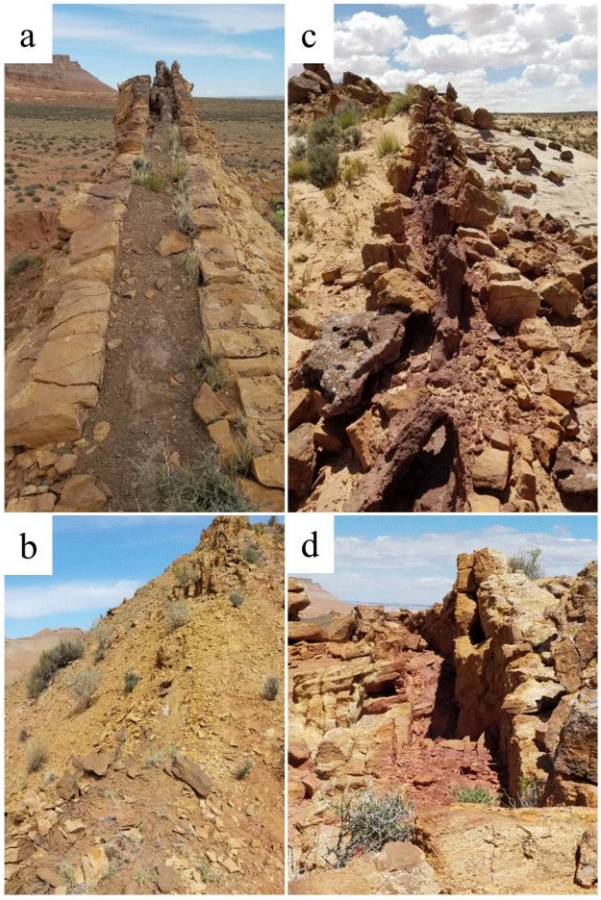

Figure 1. *Mafic Flat Top Dike showing each of the four visually distinct zones. The alteration and oxidation of the dike changes from the 'fresh' zone (a), the 'green' zone (b), the 'purple' zone (c), and the 'red' zone (d).The dike exhibits increasing oxidation from zone a through d.*

Thin sections were made from each of the four regions and petrographic analyses are under way. Bulk samples (powders and chips) were analyzed by visible to near-infrared reflectance spectroscopy (VNIR) using an ASD TerraSpec Pro; X-ray diffraction (XRD) using a Rigaku Ultima IV; and X-ray fluorescence (XRF) at Southwest Research Institute, San Antonio. This data set of bulk mineralogy and chemistry will allow us to constrain the geochemical and mineralogical variation between each zone.

Results: The Flat Top Dike is heterogeneously oxidized (based on color variation) with the alteration increasing from northwest toward the southeast. There are four main zones of oxidation along the the intrustion that can be generally characterized by the difference in color in the field and in hand sample (Figure 1). The 'freshest' sample of the dike can be found in the northwest section of the dike (Figure 1a) showing a dark black color. Moving along to the southwest the dike exhibits a yellow-green color (b), followed by a section of purple coloration (c), before the most oxidized, red section of dike (d).

Initial results from VNIR spectroscopy show iron oxidation minerals, including hematite and goethite, are present throughout the intrusion, including in the least altered samples. However, hematite and goethite occur in greater concentration in the more oxidized samples, as seen by the shape and depth of the minima of the reflectance seen at a wavelength between 600-800 nm (Figure 2). Kaolinite is present in all zones of the dike, and similar to the oxidation minerals, kaolinite signals increase in strength (more well defined minima) towards the more oxidized zones (Figure 2). In addition, VNIR spectroscopy indicates the presence of gypsum and calcite in some samples.

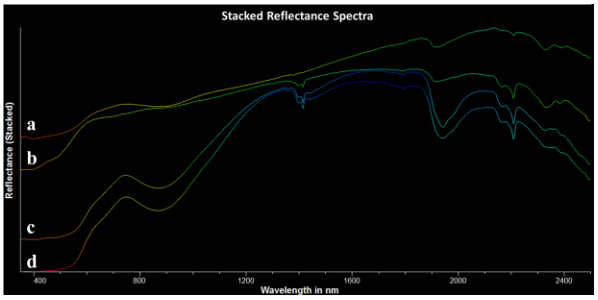

Figure 2. *Stacked VISNIR reflectance spectroscopy data from each of the four zones of the dike. Moving from top to bottom, these zones include the 'fresh' zone (a), the 'green' zone (b), the 'purple' zone (c), and the 'red' zone (d).*

Conclusions: The Flat Top Dike has undergone alteration and oxidation even in the freshest samples. Iron oxides and clays are identified across the dike. The preliminary results show a positive correlation between an iron oxide and clay minerals with an increase in macroscopic alteration (based on color) from NW to SE. Understanding the minerals present in each sample will allow us to see any major geochemical differences between each zone of the dike. This location provides a unique opportunity to study a range of alteration, from fresh to oxidized, along a single intrusive body.

On Mars, global mineralogical mapping from OMEGA of the Martian surface shows similar mineralogy (Fe/Mg and Al smectite clays) to the oxidized dike system [8]. Further, the phyllosilicates are widespread but restricted to ancient terrains [8]. CRISM spectroscopy also indicate hydrated minerals on Mars [11]. At Yellowknife Bay in Gale Crater, observations by CRISM were investigated by Curiosity, confirming the presence of iron oxides/hydroxides and smectite clays using CheMin XRD [11]. The composition of the mudstone found at Yellowknife Bay is similar to the altered Flat Top Dike [11]. Therefore, our ongoing investigation of the oxidation and alteration processs of iron and magnesium silicates in a terrestrial basalt will provide a better foundation for understanding the conditions of formation of these alteration products on Mars.

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